APPENDIX I – *Impractability of Groundwater Remediation at the Former DuPont Works Site, DuPont, WA*

I.1 Introduction

The cost for pumping and treating groundwater at the Former DuPont Works Site (Site) to meet the DNT drinking water screening level would be substantial and disproportionate to the degree of risk reduction which could be achieved. Therefore, in accordance with MTCA (WAC 173-340-360, it is impractical to consider active groundwater remediation at the Site for an end use (drinking water) that is not planned. This conclusion is based on the following:

- Site groundwater poses no risk to human health or the environment.
- Because off-Site drinking water supplies will supply more than double the full projected population of DuPont through the year 2020, Site groundwater is not currently and will not in the future be used as a drinking water source (due to a deed restriction).
- Future Site development plans will include deed restrictions as necessary to prevent drilling of drinking water supply wells;
- Even assuming a hypothetical drinking water exposure that does not and will not exist at the Site, the highest DNT concentrations currently in Site aquifers (less than 0.5 µg/L) represent a worst-case risk of less than 4×10^{-6}, which meets a risk threshold of $1 \times l0^{-5}$;
- Current DNT concentrations pose no risk to golfers, other visitors, or golf course maintenance workers who would be most likely to encounter Site groundwater on a regular basis when it is used for golf course irrigation; and
- Site groundwater poses no risk to any Site ecological environment (including Sequalitchew Creek and Old Fort Lake) or off-Site ecological environment (e.g. Puget Sound).
- Natural groundwater recovery will occur following the completed interim DNT source removal. Removal of more than 40,000 cubic yards of DNT-impacted Site soils has been completed, thus the source of DNT to Site groundwater has been removed;
- Already low DNT concentrations in Site groundwater will decline further because Site aquifers are highly permeable and DNT is mobile. This allows for natural flushing of DNT from the groundwater system and further reductions over time in the already low risk under a hypothetical drinking water scenario; and
- The current Site groundwater monitoring program will continue to document the DNT concentrations over time.

Acknowledging groundwater pump and treat systems poor historical performance in achieving drinking water standards, the existing DNT concentrations in Site groundwater would represent a reasonable remediation endpoint at sites where active remediation is under consideration or underway.

The cost to implement active groundwater remediation would be excessive, with preliminary estimates ranging between 33 and 58 million dollars. Consistent with the intent of MTCA and CERCLA, resources should be directed toward making substantive reductions in overall Site risk, which will be best accomplished at this Site by addressing other contaminants remaining in soils.

I.2 Site Groundwater Poses No Risk to Human Health or the Environment

DNT is the only constituent present in Site groundwater at concentrations above drinking water screening levels. The concentrations of DNT in Site aquifers are very low (maximum 95% UCL is less than 0.5 µg/L) and do not represent a risk as explained below.

I.2.1 Site Groundwater Poses No Risk to Human Health

Based on data collected, the highest average DNT concentration in an aquifer beneath the Site is 0.47 µg/L (95% UCL for MW-22). The MTCA drinking water screening level of 0.13 µg/L is based on a 1×10^{-6} risk level. The worst-case risk based on a hypothetical Site drinking water exposure scenario (drinking current DNT concentration in MW-22 for 30 years) is less than 4×10^{-6} which is below the MTCA risk threshold of 1×10^{-5}.

Site groundwater is not being used for drinking water under current Site conditions, and it will not be used in the foreseeable future because adequate off-Site drinking water supply exists to meet future demand. For a projected full build-out population of 10,000 people at the year 2020 (McCamett, June 1995) and an average water consumption of 150 gallons per capita day (Clark et a1, 1977; Metcalf and Eddy, 1979; Linsley and Franzini, 1979), the City of DuPont will have an estimated maximum water demand of approximately 1.5 million gallons per day (MGD). The City of DuPont's existing water system will supply this demand while maintaining excess reserve capacity. The two existing Bell Hill wells have permitted water rights of 2.0 MGD; additions to the system may include an additional well(s) at Hoffman Hill which could potentially double the supply capacity. The Bell Hill wells are located hydraulically up-gradient of the Site and are incapable of drawing water from beneath the Site. As part of the Bell Hill water rights permitting process Ecology reviewed and concurred with technical evaluations (Hart Crowser, 1991) supporting the long-term safety of the Bell Hill water supply even under continuous maximum production. Similarly, Hoffman Hill is located cross-gradient of the Site and wells drilled there would be developed to prevent drawing any groundwater from beneath the Site. Off-Site water supply from the Bell Hill and Hoffman Hill well alone will support more than double the projected population of the City of DuPont, without additional water supply development.

There is no need for drinking water wells to be drilled within the Site under any foreseeable development scenario. As a final measure of protection, Site development plans will include institutional controls, as necessary, in the form of deed restrictions to prevent drilling of wells within the Site for the purpose of water supply.

In addition, Site groundwater poses little to no risk to golfers, visitors, or golf course maintenance workers from dermal contact with irrigation water or from drinking of irrigation water. Attachment A provides a screening evaluation of potential risk to a golf course worker, the person most likely to come in contact with irrigation water.

I.2.2 Site Groundwater Poses No Risk to the Environment

DNT concentrations discharging in seeps to Puget Sound are an order of magnitude below the surface water screening level (an ARAR) of 9.1 µg/L, which is protective of marine aquatic life. DNT was not detected in Sequalitchew Creek or springs discharging to it, or in Old Fort Lake, indicating no potential risk to freshwater aquatic life.

DNT was not detected in samples of marine sediments collected at locations where Site groundwater discharges to Puget Sound or in samples of freshwater sediments from Sequalitchew Creek or Old Fort Lake.

DNT is not detectable in surface water or sediments within or adjacent to the Site, and concentrations in Site groundwater discharging to Puget Sound are below the surface water quality standards.

I.3 Groundwater Recovery Will Occur Naturally

The extensive interim DNT source removal has been successful in removing the vast majority of DNT-impacted soils from the Site. Groundwater flow rates at the Site are very high leading to rapid flushing of the aquifers. As a result, natural recovery of Site groundwater should occur relatively rapidly.

I.4 The DNT Source Has Been Removed

Been 1992 and 1995, more than 40,000 cubic yards of Site soils with DNT concentrations above 3 mg/kg were removed in the five areas where DNT was detected above 1 mg/kg (RI Areas 5, 10, 18, 25, and 31). Data from hundreds of designation samples collected from excavated soils and hundreds of verification samples collected from the excavations suggest that the vast majority of DNT mass (nearly 5,300 kg. or more than 5 tons) has been removed from these two areas. These data, and verification data from the other smaller areas, indicate that the DNT source has been effectively removed from the Site. The most important step in facilitating natural groundwater restoration is removal of the source to prevent further DNT leaching to groundwater. This has been accomplished at the Site.

I.5 Rapid Natural Groundwater Flushing in Site Aquifers

Aquifers beneath the Site are highly permeable (including the exceptionally permeable Steilacoom Gravels), resulting in estimated groundwater flow rates likely on the order of 5,000 to 8,000 feet per year (median values for the Water Table and Unconfined Sea Level Aquifers from ranges presented in Hart Crowser, 1994). The large quantities of groundwater flushing naturally through the aquifers each year will be effective in further reducing the already low residual DNT concentrations in Site aquifers. There is sufficient water moving through the groundwater system under ambient conditions to achieve natural recovery (reducing DNT to below the drinking water screening level) without attempting to supplement the process with active groundwater treatment.

A pump and treat system would involve the same mechanism for aquifer restoration as is occurring naturally via groundwater discharge from the Site (that is removal of water containing DNT from the aquifer system). In a hypothetical pump and treat system, pumpage from the Sea Level Aquifer (SLA) would be approximately equal to the quantity of water discharging naturally from the Site via the SLA. A Site pump and treat system would also include pumping from a portion of the Water Table Aquifer (WTA). Preliminary pumping rate estimates indicate that pumpage from the WTA would comprise about 20 percent and pumpage from the SLA about 80 percent, of the total water pumped in a hypothetical Site pump and treat system (pumping rate estimates discussed below). Aggressive pump and treat of both Site aquifers would provide a 25 percent increase in water removed from the aquifer system relative to natural discharge, which, in time, could decrease the aquifer restoration time by only 20 percent relative to natural flushing. [A 20 percent decrease in time is based on a simple “batch flush” model ($t = \ln[Ct/Co] * PV * R / Q$; EPA, 1988). Increasing flow rare, Q, by 0.25 decreases restoration time, t, by 0.20 in this model. Other values in the equation would be constants for this demonstration.]

I.6 Technical Infeasibility Considerations

Groundwater pump and treat is the only groundwater remediation technology which could be applied at the Site for the following reasons:

- Groundwater which would be targeted for remediation is deep (100 to 200 feet below surface) and laterally extensive, preventing use of impermeable barriers, gates, or other groundwater isolation techniques;
- DNT has low volatility, preventing use of sparging or other venting technologies;
- Although DNT can be degraded through natural in situ processes, only biological degradation could potentially occur in Site aquifers and attempting to enhance this process as part of a remediation program would likely be infeasible;

- DNT readily degrades by photolysis (half-life on the order of days; Etnier, 1987), but this process will not occur in aquifers;

- DNT can be transformed to formic and acetic acids, but only at temperatures at which water would not persist (520°F; Etnier, 1987); and

- DNT in water degrades through biological processes under some aerobic and anaerobic conditions (Spanggord. 1980; Etniert 1987), but the metabolism of DNT is strongly dependent on environmental conditions and the presence of viable microorganisms (ATSDR, 1989). Biodegradation of DNT may be occurring naturally in Site aquifers, yet attempting to establish or enhance appropriate natural microorganism populations (e.g., by introducing nutrients) in Site aquifers would likely be infeasible because of the size of the Site and the substantial depth of the aquifers.

The National Research Council (NRC) Committee on Ground Water Cleanup Alternatives' published report lists "conventional pump and treat" as the only effective technology (out of 12 technology categories) for dissolved constituents, which are non-reactive or non-volatile (NRC, 1994). DNT in Site groundwater falls into this category.

In a pump and treat scenario, groundwater extracted from Site aquifers would be treated most cost-effectively using granular activated carbon (GAC). Recent studies at another site have demonstrated that GAC is considerably more cost-effective to use than advanced oxidation technologies (e.g. UV/Ozone) at low influent concentrations (Hart Crowser, 1993).

The historical performance of groundwater pump and treat systems in restoring aquifers to drinking water standards has been poor suggesting that groundwater pump and treat to achieve drinking water standards everywhere in an aquifer may be technically infeasible. This fact is widely acknowledged within the environmental industry, including the EPA (Travis and Doty, 1990; Doty and Travis, 1991; EPA, 1992; Makdisi, 1994). Of 77 pump and treat sites evaluated in the NRC (1994) report, eight small sites (pumping rates between 1 and 37 gpm; 5 were service stations) with volatile organic compounds (VOCs) had apparently achieved cleanup goals, some of which had the benefit of using venting/sparging to enhance VOC removal. In contrast, the Former DuPont Works Site is very large and hydro-geologically complex and DNT would need to be extracted solely through conventional groundwater pumping. Therefore, the time required for pump and treat to achieve the DNT drinking water standard throughout the Site could be approximately 10 to 20 years or longer, if it were to be implemented. One-half of the sites evaluated by the NRC have already been pumping and treating for at least 10 years without achievement of drinking water standards (NRC, 1994).

At other sites where groundwater concentrations are orders of magnitude higher than at this Site, pump and treat may make sense for reducing concentrations (thus reducing risk) to the extent practical. General evaluations of pump and treat performance suggest it would not be unreasonable to expend 50 percent of available resources (time and money) initially reducing groundwater concentrations by 90 percent, and then expend the remaining 50 percent attempting to remove the residual 10 percent (i.e., below some low asymptotic level). Maximum DNT concentrations at the Site would likely fall within the final one percent at sites where active groundwater remediation is undertaken.

I.7 Cost of Active Groundwater Remediation

The cost to implement active groundwater remediation (pump and treat) at the Site would be excessive, primarily because of the high groundwater flow rates and resulting large volume of water which would need to be extracted, treated, and reintroduced to Site aquifers.

I.7.1 Groundwater Pumping Rate Estimates.

The following analytical equation presented in Keely (1984) was used to estimate the pumping rate needed to capture all Site groundwater with DNT concentrations above 0.13 µg/L in the Water Table Aquifer and in the Sea Level Aquifer:

(1) Max width of capture zone (w) = Q / H v n (I)

where:

Q = pumping rate in ft^3/day;
H = initial saturated thickness in feet;
v = average linear groundwater velocity in ft/day; and n = effective porosity (dimensionless).

Because average linear velocity (v) is equal to Ki/n, effective porosity drops out of the equation. Rearranging the equation to solve for pumping rate (Q) then gives:

(2) Q = w H K i (2)

where:

Q, w, and H are defined above;
K = hydraulic conductivity in ft/day; and
i = hydraulic gradient in ft/foot.

Equation (2) was solved using Monte Carlo simulation to develop a probabilistic range of pumping rates which encompasses reasonable ranges of uncertainties in hydraulic parameters. The equation was solved independently for the Water Table Aquifer (assuming capture of groundwater in Area 18 with DNT above 0.13 µg/L) and the" Sea Level Aquifer (assuming capture of all groundwater in the Sea Level Aquifer with DNT above 0.13 µg/L) .The flow rates from the two aquifers were added to provide an estimated total system now rate for a hypothetical Site pump and treat system.

Hydraulic parameters were assigned assumed probability distributions based on information presented in the initial Draft RI (Hart Crowser, 1994). The assumptions follow, and are provided in Attachment B.
Water Table Aquifer (WTA) Assumptions:

- Hydraulic conductivity (K) was assigned a lognormal distribution with geometric mean of 5 x 10^{-2} cm/sec and a standard deviation of 10 percent of the mean. [This compares favorably with reliable pumping test results from Fort Lewis which provide a K estimate for the Water Table Aquifer (WTA) of 2 x 10^{-1} cm/sec, which is higher than the range presented in the initial RI. This value is consistent with the coarse-grained nature of the WTA. Based on this value and other WTA pumping test results presented in the initial Draft RI, we assumed 5 x 10^{-2} cm/sec as our best judgment estimate of an average K value. Because these flow rate estimates are most sensitive to uncertainty in K (which can vary by orders of magnitude) relatively small standard deviations (for both aquifers) were assumed about the mean values in an effort to provide a more tightly constrained, thus useful, range of resultant flow rates.]

- Horizontal hydraulic gradient (i) estimates for the WTA, ranging from 0.02 to 0.05 ft/ft are based on water table elevation contour maps. Hydraulic gradient for the WTA was assigned a triangular distribution with minimum, most likely, and maximum values of 0,02, 0.035 (midpoint of range), and 0.05 ft/ft, respectively,

- The thickness of the WTA was assigned a triangular distribution with minimum, most likely, and maximum values of 10, 30, and 50 feet, respectively, based on geologic information from drilling Site monitoring wells.

The width of the WTA to be captured was assigned a triangular distribution with minimum, most likely, and maximum values of 1,200, 1.600, and 2,000 feet, respectively, based on the locations of interim DNT source removal excavations and groundwater flow directions presented in the Draft RI.

I.7.2 Sea Level Aquifer (SLA) Assumptions

- Hydraulic conductivity was assigned a lognormal distribution with geometric mean of 1 x 10^{-1} cm/sec (midpoint of the range presented in the Draft RI) and a standard deviation of 10 percent of the mean (as discussed above).

- Horizontal hydraulic gradient (i) estimates for the Unconfined SLA ranging from 0.005 to 0.02 ft/ft were based on water table elevation contour maps. Hydraulic gradient for the SLA was assigned a triangular distribution with minimum, most likely, and maximum values of 0.005, 0.013 (midpoint of range), and 0.02 ft/ft, respectively.

- The thickness of the SLA was assigned a triangular distribution with minimum, most likely, and maximum values of 80, 100, and 120 feet, respectively based on geologic information from drilling of a deep test well north of the Site which penetrated approximately 120 feet of saturated Steilacoom Gravels (Unconfined Sea Level Aquifer).

- The width of the SLA to be captured was assigned a triangular distribution with minimum, most likely, and maximum values of 2,000, 2,500, and 3.000 feet, respectively, based on the distribution of DNT within the Unconfined Sea Level Aquifer.

Using these parameter distributions as input, equation (2) was run as a Monte Carlo simulation using Crystal Ball software, a forecasting and risk analysis add-on to the Excel spreadsheet. The equation was solved for each aquifer 5,000 times by randomly selecting parameter values from the aquifer-specific probability distributions outlined above, and summing the flow rates from both aquifers into an estimated total system flow rate. The 5,000 estimates of the total system flow rate were automatically compiled into a probability distribution for which percentiles are provided. Attachment B provides the supporting information for the now rate estimates (including assumptions, forecasts, and statistical output).

Using the probability distribution for total system flow rate, we selected a range of system flow rates corresponding to 95 percent and 25 percent probabilities (i.e., a reasonable range of likely outcomes) for the purposes of developing a range of cost estimates. Based on the Monte Carlo simulation, the 5^{th} percentile value was approximately 3,500 gpm (95 percent probability that the flow rate would be at least that high; refer to page B-2 in Attachment B) and the 75^{th} percentile value was approximately 7,000 gpm (25 percent probability that it would be that high). This range of flow rates appears reasonable when compared with a relatively large-scale pump and treat system operating at Ponders Corner, approximately 5 miles from the Site, which had pumped 2,000 gpm from only the lower permeability portion (Advance Outwash) of the Water Table Aquifer (EPA, 1992).

I.7.3 Preliminary Cost Estimate for Groundwater Remediation

Using the estimates for pumping rates presented above, preliminary estimates of cost range from approximately $33 million (assuming pumping, treatment by granular activated carbon (GAC), and reintroduction to the aquifer of 3,500 gpm [5 MGD] for a 10-year duration) to approximately $58 million (assuming pumping, treatment, and reintroduction to the aquifer of 7,000 gpm [10 MGD] for a 20-year duration). A ten (10) year duration of operation was based on the findings of the NRC (1994) report, where one-half of all systems studied have already been operating 10 years or more (with a maximum of 21 years). As such, the twenty (20) year duration was used as the high-end estimate for the purposes of developing cost estimates.

The cost estimates were developed using EPA's Cost of Remedial Action (CORA) Model (CH2M Hill, 1990). The preliminary cost estimate included the following components;

- Installation of extraction wells;

- Installation of conveyance (piping) systems;
- Purchase and operation of granular activated carbon (GAC) treatment system (including carbon change out and off-Site thermal regeneration);
- Installation of re-introduction wells to return treated groundwater back to the aquifers (also used to help control saltwater intrusion in the Sea Level Aquifer);
- Performance monitoring for full period of operation; and
- Operation and maintenance of all systems for period of operation.

Table 1 provides a summary of CORA's estimated costs for constructing (capital costs) and operating and maintaining (O&M costs) a groundwater pump and treat system at the Site under four assumed scenarios (5 MGD for 10 or 20 years, and 10 MGD for 10 or 20 years). These cost estimates do not include pilot testing or engineering design.

I.8 Conclusions

For the Former DuPont Works Site, there is a clear case that the cost to implement active groundwater remediation would be substantial and disproportionate to any risk reduction it could achieve, as specified in MTCA.

- First, there is no risk to human health or the ecological environment posed by DNT in groundwater under any current or foreseeable future land use of the Sire; ample off-Site water supply exists to meet all future drinking water demand, and intuitional controls will be implemented, as necessary, during future Site development to prevent withdrawal of Site groundwater for drinking water use;
- Second, the DNT source at the Site has been removed so that natural recovery will be effective in further reducing the extremely low DNT concentrations currently detected in Site groundwater;
- Third, concentrations in Site groundwater are already low enough that active groundwater pump and treat would likely be little or no more effective than natural flushing in removing the last residual DNT from Site aquifers; and
- Finally, the cost to undertake groundwater pump and treat would be excessive, particularly since it would not provide a substantive reduction in Site risk.

The intent of MTCA and CERCLA is to focus cleanup resources to reduce overall Site risk under current and future land use. This will be accomplished at the Former DuPont Works Site by addressing Site soils, not Site groundwater.

Table I-1 – Summary of Cost[1] Estimates for Implementing Groundwater Pump and Treat for the Former DuPont Works Site

Scenario	Capital Cost	O & M Costs[2]	Total Cost
5 MGD for l0 years	$16.5	$16.7	$33
5 MGD for 20 years	$16.5	$23.0	$40
10 MGD for 10 years	$20.0	$27.0	$47
10 MGD for 20 years	$20.0	$38.0	$58

Notes:
(1)Cost estimates developed using CORA -EPA's Cost of Remedial Action Model (CH2M Hill, 1990). All costs in millions.
(2)Present worth based on 10% annual interest rate.

I.9 References for Appendix I

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